

September 2014

THE CASE OF THE IMPRUDENT WADERS: JPL BLDG. 277 WATER INCIDENT

Some of the approximately 100 JPL laboratories and specialized fabrication and test facilities are engaged in activities critical to JPL missions despite being co-located with office space like in Building 277. Hence, the potential impact of interrupting infrastructure services may not be obvious. In early 2014, routine Building 277 maintenance that was performed by a facility maintenance contractor initiated a chain of events that resulted in a Type C mishap, early termination of a life test, and loss of all test samples. This case study discusses the need to highlight facilities that host critical operations, improve communication between the building users and infrastructure organizations, train personnel to recognize hazardous conditions, and institute adequate test safeguards.

Background: Building 277 Facilities



JPL Building 277

It is often convenient to co-locate specialized engineering and scientific facilities with the permanent office space that houses the corresponding specialists. Bldg. 277 furnishes office space for both the JPL Thermal Energy Conversion Technologies Group (3464) and the JPL Electrochemical Technologies Group (3463). In the basement of the building, however, is located the Thermoelectric Conversion Technologies Testing Laboratory (TCTTL) and the Battery Development & Test Laboratory, managed by Groups 3464 and 3463, respectively. The basement location is more suitable than an upper floor for the heavy equipment and hazardous chemicals in the two labs.



TCTTL facility for testing of advanced thermoelectric materials

Most JPL spacecraft have been powered by panels of solar cells that convert sunlight to electricity. The power requirements of deep space missions, however, sometimes mandate use of a radioisotope power generator such as the one now used to power the latest Mars rover. Converting heat from radioactive decay into electricity does not require sunlight, but the technology is more complex than solar cells. The TCTTL is a one-of-its-kind facility for thermoelectric materials synthesis and characterization. Essential TCTTL labs, such as the Performance & Life Testing Lab, are equipped with an emergency generator and an uninterruptible power system so they can operate without interruptions.

“The Case of the Imprudent Waders”

JPL Bldg. 277 water incident

Proximate cause:

Shutting off the chilled water supply to the Bldg. 277 basement laboratories while tests were being conducted.

Root Cause:

Inadequate communications, safety training, test safeguards, and maintenance task coordination/planning.

The Battery Lab supports advanced energy storage and power technologies for both aerospace and terrestrial applications, such as:

- Testing of primary, rechargeable and thermal flight batteries for robotic spacecraft.
- Flight battery performance modeling.
- Regenerative fuel cell system design and testing.

Building 277 is one of more than 175 buildings on the JPL campus-- all maintained by a small staff of JPL facilities engineers and by a Maintenance and Operations (M&O) contractor. Among the duties of the M&O contractor is maintenance of over 2000 JPL HVAC assets such as chillers, boilers, and air conditioners.

The Mishap

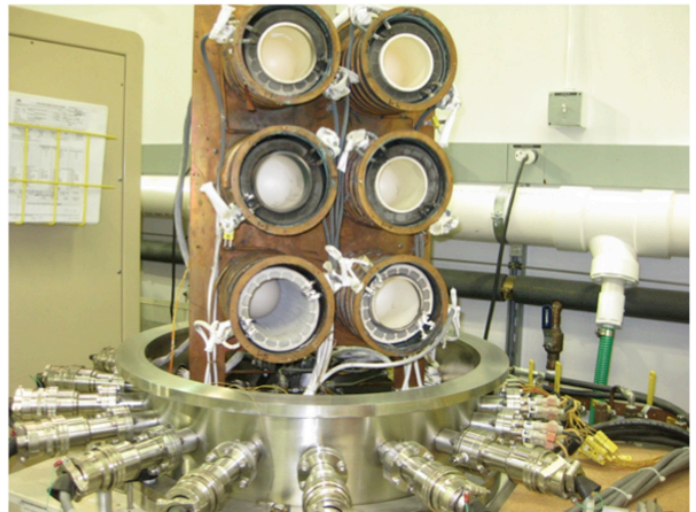
The annual preventative maintenance of the Building 277 water chiller (cooling tower) was performed on February 1, 2014 (References (1) and (2)). This activity involved the removal of autumn leaves and other routine maintenance. As it was a Saturday when most facility staff would be absent, it was a convenient time for the JPL M&O contractor to shut down the chiller, pump, and chilled water that service the TCTTL. However, this work was not coordinated with the building coordinator or with the technicians in the TCTTL lab, and critical testing equipment was not safeguarded or taken off line. The lack of chilled water caused elevated temperatures in the lab's test chambers, resulting in the failure of a brazed joint in Test Chamber #41's closed-loop water cooling system. When their work was completed on Saturday afternoon, the maintenance crew restored the flow to the building's chilled water system. Because the brazed joint cracked due to the high temperature, the chilled water leaked through the crack and entered into the test sample areas of Test Chamber #41. This caused a loss of pressure in the chamber that allowed the water to leak out of the chamber and onto the facility floor.

The next morning, a research technologist entered the TCTTL to check on his experiment and discovered a half-inch of water covering the entire lab floor. He entered the room with the standing water to check for the source of water. Unable to determine the source of the leak, he called an off-duty lab technician. Once the technician arrived, they found water coming out of Chamber #41. The two JPL employees began to remove the pooled water with a wet/dry vacuum; they also used a ceiling-mounted crane to open the leaking Test Chamber #41, releasing an additional 50 gallons of water that had been trapped inside the chamber. During this activity, the two employees were unaware of the possibility that the pooled water might be energized given the many live electrical cables on the floor of the lab.

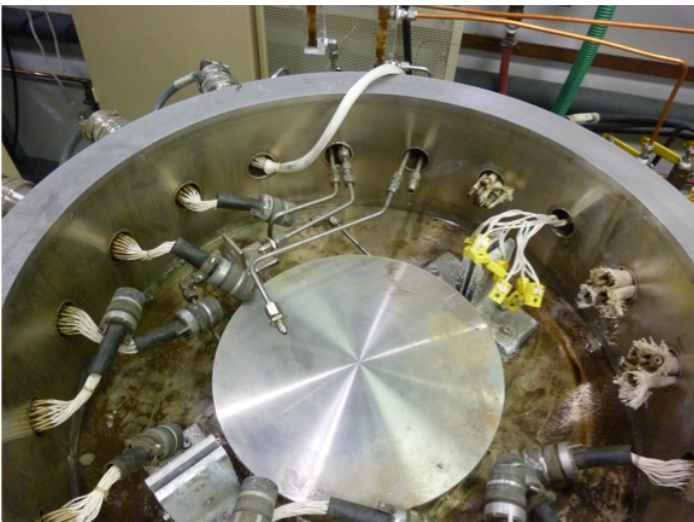


Close-up of Test Chamber #41 showing the remaining water pooled in the chamber

At the time of the water leak, the life test on 18 tellurium, antimony, germanium, and silver material samples had been running continuously in Test Chamber #41 since June 2012, and 16,000 test hours had been accumulated on the samples. The samples were being tested in six separate furnaces, and



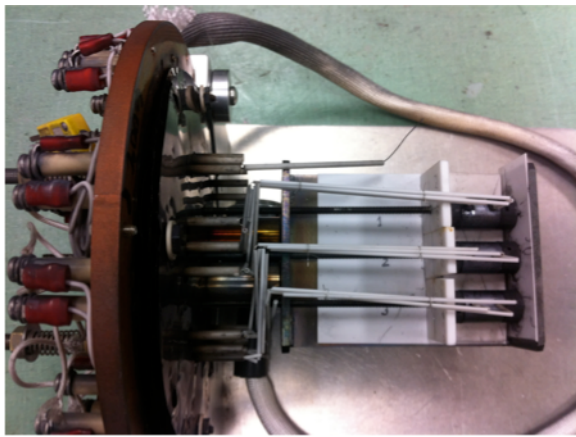
Furnaces installed inside a test chamber, which operates in an argon atmosphere



Test Chamber #41 with the top/cover removed.

immersion in the leaked water quenched the samples. The quenching caused the early termination of the life test and loss of all test samples. The purpose of the life test was chiefly to better quantify changes in thermoelectric properties over time at high temperatures to predict degradation of Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) power output.

In the adjacent Battery Lab, the room temperature increased to 95° F (35° C) from the nominal temperature of 68° F. This was likely due to the cooling unit running with no coolant water. The MSL mission simulation battery cells experienced a temperature of above 86° F (30° C). This is the first time these cells have reached this operating temperature; this thermal excursion is likely to have some minimal effect on cell lifespan.



Instrumented test samples mounted on the furnace doors/covers

Other test chambers and test samples in the building, as well as Mars Science Laboratory battery cells under test in the Battery Lab, could have been compromised if the chilled water had not been restored in a timely manner. In addition, there was substantial damage to TCTTL test hardware, and the facility cleanup took 50 hours. The incident was classed as a "NASA Mishap Type C," in which the total direct cost of the mishap was between \$50,000 and \$500,000.

Conclusions

The subsequent investigation found there to have been some miscommunication wherein a lab staff member thought he had clearly communicated to the contractor that the weekend work should not be performed. Nevertheless, the work appears to conflict with an earlier agreement that the M&O contractor notify the Building Coordinator prior to performing any work on Building 277. Although the flood was discovered Sunday morning, neither the contractor nor the JPL Facilities organization were informed of the incident on Sunday.

Despite the presence of the TCTTL and the Battery Lab, Building 277 was not registered as a "JPL Critical Facility." Such registration can potentially have the positive effect of

requiring written concurrence prior to initiating nonessential infrastructure support services that could disrupt critical JPL operations. However, it is unclear whether either the M&O contractor or the JPL Facilities organization understood the impact of a Building 277 chiller shutdown.

Aftermath

Following the incident, action was taken to add Bldg. 277 to the critical facilities list. In addition, the line organization took on the following action items:

- Repair the damaged equipment (heaters, ion gauge tube, convection gauge tube, thermocouples, vacuum gauge readout, heat exchanger)
- Conduct safety training
- Develop a contingency plan for lab safety
- Improve coordination with JPL Facilities and the M&O contractor
 - Communication prior to work start
 - Plan actions to take in response to an alarm
 - Plan actions to take in response to an incident

Discussion

1. What was the root cause of the mishap? [Inadequate communications, safety training, test safeguards, and maintenance task coordination/ planning]
2. If the chiller shutoff had occurred on a weekday, what factors might have affected the outcome? [Are there processes or procedures that might need to proceed differently if such an incident occurs on a weekend versus a weekday?]
3. What could the line organization have done to prevent the mishap? What could a project manager do to prevent (a) such a serious threat to personnel safety and (b) potential damage to flight hardware? [Start a conversation between Section 346, JPL Facilities, EMCOR, and the Safety Office. Train lab personnel on the process for notifying personnel of work to be performed by EMCOR on/in a building. Improve the process?]
4. What other infrastructure services, if abruptly terminated, and what other routine maintenance tasks, could interrupt or harm flight projects or critical operations? [e.g., a/c for certain computers; see Lessons Learned #2216, #8501]

How about other service cutoffs impacting the safety of people who work for you? (What are your responsibilities in that regard?)

5. What specific test safeguards could have been implemented? [Place alarms on critical hardware cooling systems such that a shutdown will trigger notification of

key personnel. Where feasible for heated test equipment, an interrupted coolant flow should trigger unit shutdown to prevent overheating. Is there a procedure affecting unmonitored tests.]

6. Might there have been any cultural factors influencing the actions of the “imprudent waders?” How about the actions of the contractors? [Excessive focus on the completing the mission at all costs?]
7. If the responsible parties fully understand their duties regarding interruptions to critical operations, might having “single-string individuals” still pose a continued risk? [What happens if a key point-of-contact is sick, or if there is a change in personnel: is there sufficient training in the organization to know they need to coordinate with the appropriate POC prior to any maintenance?]
8. How might JPL and your line organization disrupt the “Cycle of Forgetfulness,” in which the widespread recognition of process escapes following a mishap fades over time?

Additional References

- (1) JPL Mishap Report No. 2979, February 2, 2014.
- (2) Naomi Palmer, “Bldg. 277 Water Incident: Feb 1, 2014,” February 13, 2014.
- (3) “Ban Nonessential Infrastructure Support Services That Could Disrupt Critical Mission Operations,” Lesson Learned No. 2216, NASA Engineering Network, August 18, 2009.